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HABITAT SELECTION BY TAWNY FISH-OWLS (*KETUPA FLAVIPES*) IN TAIWAN

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ABSTRACT.—Four radio-tagged Tawny Fish-Owls (*Ketupa flavipes*) were studied to determine their choice of roosting and foraging/resting habitats in Taiwan. A total of 51 roost sites were located in two territories measuring 6.7 and 5.7 km in length. Owls selected old-growth forests more than expected according to availability and tended to roost uphill during late spring and fall. They foraged along streams more frequently than expected ($P < 0.05$) and along creeks less than expected ($P < 0.05$) with use of small creeks and fish farms increasing after streams flooded.

KEY WORDS: *Tawny Fish-Owl*; Ketupa flavipes; *radio-telemetry*; *territory*; *habitat selection*.

Selección de habitat de *Ketupa flavipes* en Taiwan

RESUMEN.—Cuatro *Ketupa flavipes* dotados de radiotransmisores fueron estudiados para determinar la selección de perchas, forrajeo y habitats de descanso en Taiwan. Un total de 51 sitios de descanso fueron localizados en dos territorios de 6.7 y 5.7 kms de longitud. Los buhos seleccionaron bosques maduros mas de lo esperado de acuerdo a la disponibilidad y tendían a posarse cuesta arriba a finales de la primavera y el otoño. Forrajearon a lo largo de los arroyos mas frecuentemente de lo esperado ($P < 0.05$) y a lo largo de los riachuelos menos de lo esperado ($P < 0.05$) utilizando los riachuelos y granjas piscícolas en época de inundaciones.

[Traducción de César Márquez]

There are four species of fish-owls in Asia in the genus *Ketupa* and three species in Africa in the genus *Scotopelia* (Fogden 1973). Except for descriptions of the nesting biology and circadian rhythm of the Tawny Fish-Owl (*Ketupa flavipes*) (Sun and Wang 1997, Sun et al. 1997), little is known about this rare and secretive species (Voous 1988). Herein, we present data on the breeding territories and habitat selection of this species.

METHODS

We studied Tawny Fish-Owls at Nanshih Stream in Fusan village (24°48′N, 121°30′E; 400 m elevation), 30 km south of Taipei, Taiwan. The main stream is fed by three streams 10–30 m in width (Hawun, Chakung and Talolan) and by nine creeks 2–5 m in width. At the village, there are four fish farms where rainbow trout (*Oncorhynchus mykiss*) and/or ayu (*Pleooglossus altivelis*) are raised. Vegetation in the area consists mostly of tropical rainforests dominated by *Ficus* and Lauraceae (Taiwan Forestry Bureau 1995) on eastern and southern banks of streams Plantations of Makino bamboo (*Phyllostachys makinoi*) and *Cryptomeria japonica*, as well as farmland and human settlements, occur on western banks. Native riparian forests bordering the streams supported large epiphytic bird's nest ferns (*Pseudodrynaria coronans*) on mature trees >1 m in diamter.

We captured four Tawny Fish-Owls with a variety of foot-snare traps while they foraged or rested along stream banks on tree branches, or on the banks of ponds at fish farms. The owls were banded, measured and radio tagged prior to release. Radio transmitters (MD-205; Telonics Inc., Mesa, Arizona, U.S.A.) weighed 70–80 g (<3.5% body mass) and had a lifespan of approximately 2 yr. Radios were attached with a backpack harness of wire (1.5 mm in diameter) placed inside tubular teflon ribbon.

Owls were tracked using a directional, hand-held H-antenna with a Telonics TR-2 receiver and locations were obtained by triangulation taking at least two bearings each time. If an owl moved while being tracked, new bearings were taken. Most owl locations were obtained along a road parallel to and <150 m from the streams.

Radio locations were plotted on habitat maps made from 1:10 000 aerial photos.

We radio tracked each owl 1–2 times daily during daylight hours to determine roost sites. Due to the bearing-induced inaccuracy of triangulation, only owl locations with error polygons within a specific riparian habitat patch were included in the analysis of roosting habitat selection. We defined a fragmented old-growth forest as one that was opened by logging or was <100 m of a road. Other features of roost sites, such as the distance to water, edge and human developments (e.g., villages or roads) were also measured. To determine foraging habitat use, we radio tracked each owl for 1–1.5 hr at night. This sampling interval was assumed to give independent locations since it was long enough for owls to move to any location within their territories (Lair 1987). We assumed all owls were involved in foraging activity during our tracking because of the difficulty in distinguishing resting from foraging behavior at night. Owl locations with error polygons centered ≤100 m from water were categorized as either stream or creek habitat, depending on their stream order (streams 3–4; creeks 1–2); otherwise, they were classified as riparian habitat.

We calculated the percent area of each water course (≤100 m from streams or creeks) and riparian forest (>100 m from the streams or creeks) within 500 m of either side of a 14-km section of Nanshih Stream (ca. 1130 ha) by overlying an aerial photograph (1:10 000) with a 1 × 1 cm grid matrix and counting the number of intersecting triangulation points within each habitat type. We used five riparian cover types: old-growth forest, second-growth forest, forest plantation, grassland and farmland/village. Each point was checked to determine if there had been any recent changes in cover type. To determine owl selection of roosting and foraging habitats, we used the percent area of each riparian and water cover type for available habitat values and the percent of roosting and foraging sites in each cover type for habitat use values.

Chi-square analysis (Conover 1980) was used to determine if actual habitat use differed from expected (Neu et al. 1974). We used Wilcoxon signed-rank tests (Conover 1980) to compare owl roost distances to human development and to edge types (e.g., second-growth forest, plantations and shrub/grass). Data were analyzed with the Statistical Analysis System (SAS Institute 1987).

RESULTS

Four owls were captured between September 1993–August 1996. A pair of owls (W503-male, W513-female) was captured at Fusan fish farm in September 1993 (Fig. 1). The pair was tracked for about a month until the transmitters fell off when the harnesses broke. The male and female were recaptured in May 1995 and August 1995, respectively, near the Hsiensen fish farm. Based on the radio locations in 1995–96, this pair continued to use the same territory used in 1993. It included a stretch of Nanshih Stream and its three main tributaries (Talolan, Chakung and Hawun), a linear distance of 6.7 km.

In October 1994, a subadult owl (W508) was captured and radio tagged at the Hsiapen fish farm (Fig. 1). It moved to the Loshanchun fish farm and remained there for about three months before leaving the area. It flew over the adjacent Fusan territory and wandered along the upper stretch of Talolan Stream and Maen, Wuchun and Tunlu Creeks in January–February 1995. In early February, it returned to the Loshanchun fish farm after an untagged owl was shot and killed at the Hsiapen fish farm. In late April, it left and returned to Talolan Stream. We found it once in the Fusan territory and it sometimes roosted near the Hsiensen fish farm while owls W503 and W513 nested on the opposite side of Chakung Stream. We lost the signal of W508 in May 1996 and never found it again.

A second adult owl (W494) was radio tagged in this same area in early June 1995 (Fig. 1). This owl and its untagged mate moved into the vacant territory of the owl killed at Hsiapen fish farm in February. The pair did not feed at a fish farm until November 1995 when W494 foraged at Loshanchun fish farm. This territory was 5.7 km in length. The two breeding territories were mutually exclusive with a boundary somewhere near the mouth of Awang Creek.

We located a total of 51 different roost sites along Nanshih Stream based on 106 radio locations (Fig. 2). Each Tawny Fish-Owl used 14–17 roost sites over the study period. Roost sites of W494 and W508 were clustered in a riparian old-growth forest near the Loshanchun and Hsiapen fish farms across Nanshih Stream. Two of 16 roost sites were near Fusan fish farm (<500 m) and W503 and W513 used them most often with 40 of 64 radio locations occurring there.

On 10 occasions, W503 and W513 roosted <100 m from each other) but, on 6 d, they roosted as far as 2 km from each other, with the male always near the territory boundary at Maen Creek. This happened whenever the pair from the Hsiapen territory were found at the upper stretch of Talolan Stream.

Roost sites ranged from 20–550 m ($\bar{x}$ = 138 ± 85 m, ±SD) from water and 29 roost sites (56.9%) were located <200 m from water (Fig. 2). Most roost sites (82.4%) were situated on eastern and southern banks of streams where disturbance by people was minimal. Owl roosts were usually located farther from human developments ($\bar{x}$ = 418.3

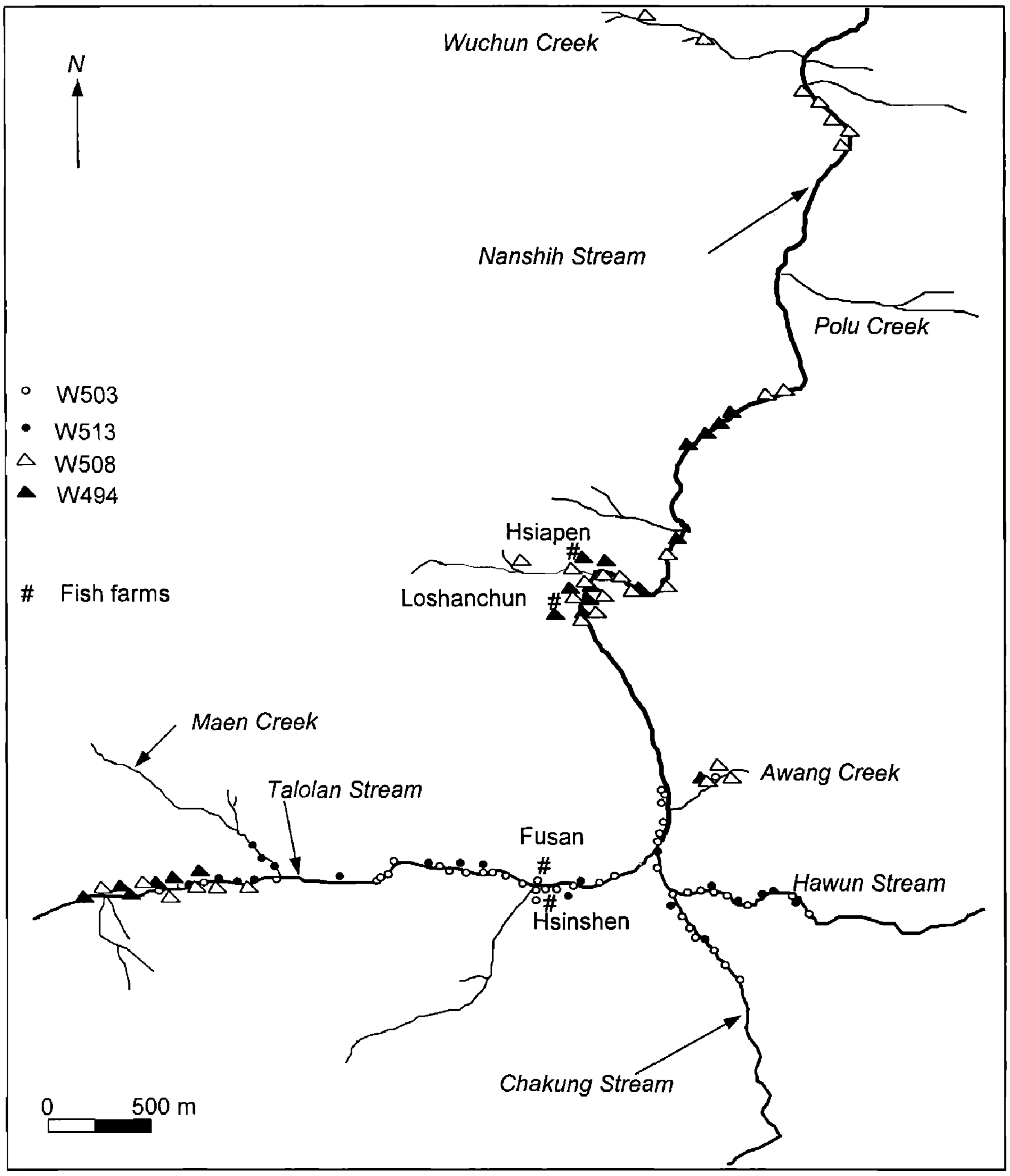

Figure 1. Nightly radio locations of four radio-tagged Tawny Fish-Owls in two territories at Nanshih Stream from September 1993–August 1996.

± 323.5 m), such as villages and roads, than from edges such as second-growth forest, plantation, and shrub/grass ($\bar{x}$ = 263.7 ± 167.7 m; Wilcoxon Signed-rank test, $P = 0.001$).

Use of roosts varied with seasons (Fig. 2). In the colder months of winter and early spring, the owls tended to roost in the vicinity of streams, while from late spring to fall, they shifted to roosts located uphill from streams.

Roosting habitat use did not vary among owls ($\chi^2 = 1.97$, df = 6, $P = 0.92$; Table 1) and they all chose old-growth forests more often than excepted (Bonferroni Z test, $P < 0.05$). Fragmented old-growth forest was used slightly more or less than expected without significance ($P > 0.05$). Highly-disturbed habitats such as second-growth forest, plantations, grassland, farmland and villages were significantly avoided by the owls ($P < 0.05$).

We had a total of 303 radio locations of owls at night. They showed that owls used water as opposed to riparian habitats more often ($\chi^2 = 844.8$, df = 1, $P = 0.001$). They also foraged along streams more frequently than creeks ($\chi^2 = 12.5$, df = 1, $P = 0.001$). Use of streams was affected by water level ($\chi^2 = 86.9$, df = 4, $P = 0.001$; Fig. 3). They foraged at fish farms more during periods of medium water level and at creeks when water levels were high.

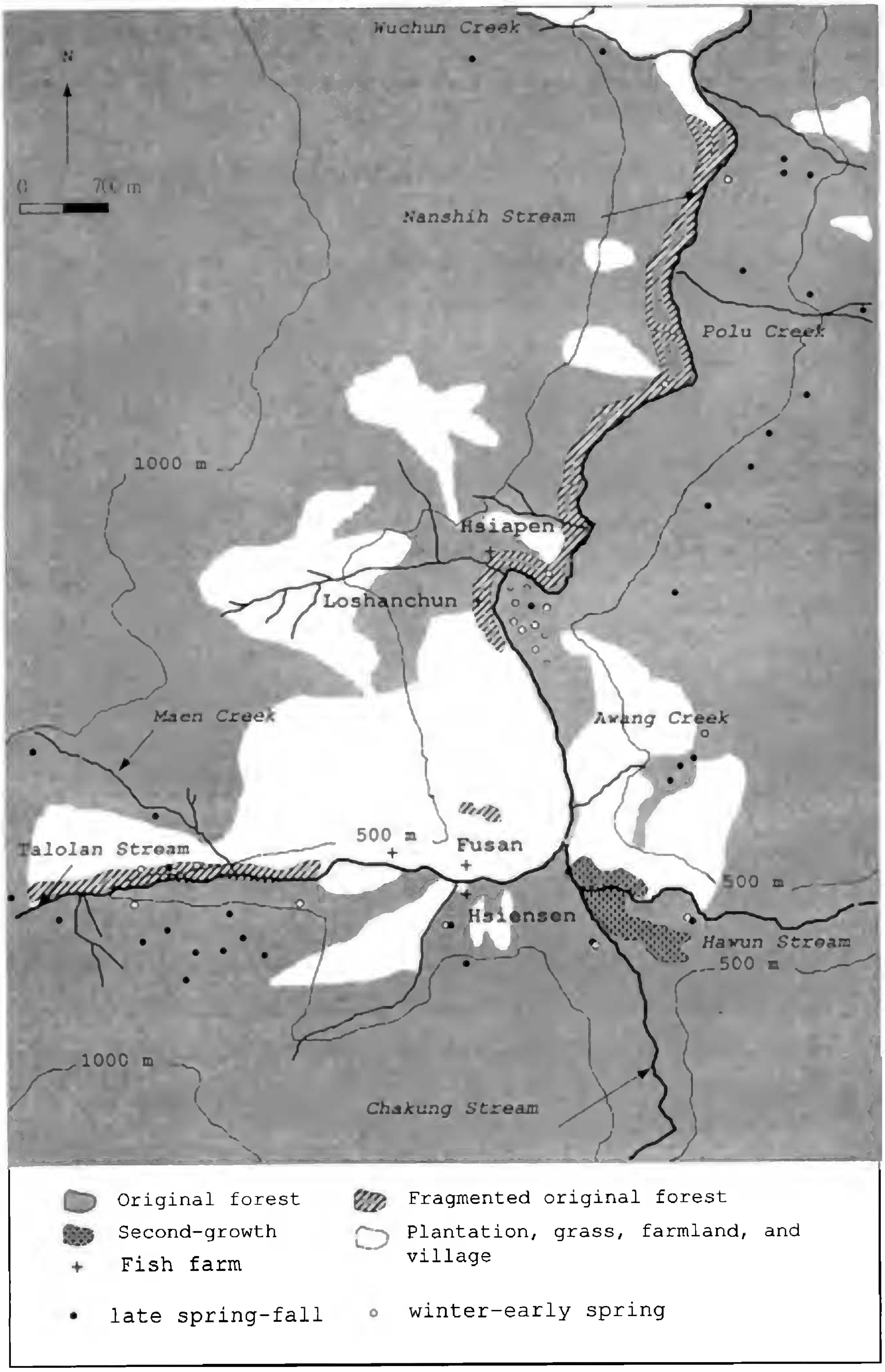

Figure 2. Roost sites of four radio-marked Tawny Fish-Owls at Nanshih Stream from September 1993–August 1996. Black dots indicate summer to mid-fall roost sites and white dots indicate late fall to spring roost sites.

Table 1. Occurrence of Tawny Fish-Owl roost sites in three cover types of a 1300-ha area in Nanshih Stream, Taiwan

OWL	COVER TYPE[a]	NUMBER OF ROOSTS	PROPORTION OF ROOSTS	BONFERRONI INTERVAL (95% CONFIDENCE INTERVAL)
W503	Old-growth forest	45	0.918	$0.827 \leq P1 \leq 1.010$
	Fragmented old-growth	3	0.061	$-0.030 \leq P3 \leq 0.068$
	Highly-disturbed habitat[b]	1	0.021	$-0.020 \leq P2 \leq 0.141$
W513	Old-growth forest	14	0.875	$0.682 \leq P1 \leq 1.068$
	Fragmented old-growth	2	0.125	$0.000 \leq P3 \leq 0.000$
	Highly-disturbed habitat	0	0.000	$-0.070 \leq P2 \leq 0.318$
W508	Old-growth forest	29	0.935	$0.832 \leq P1 \leq 1.039$
	Fragmented old-growth	2	0.065	$0.000 \leq P3 \leq 0.000$
	Highly-disturbed habitat	0	0.000	$-0.040 \leq P2 \leq 0.168$
W494	Old-growth forest	10	0.909	$0.706 \leq P1 \leq 1.112$
	Fragmented old-growth	1	0.091	$0.000 \leq P3 \leq 0.000$
	Highly-disturbed habitat	0	0.000	$-0.020 \leq P2 \leq 0.144$

[a] Proportions (expected use) of each cover type are 0.575 (old-growth forest), 0.116 (fragmented old-growth forest) and 0.309 (highly-disturbed habitat).
[b] Includes second-growth forest, forest plantation, farmlands, grassland and village.

DISCUSSION

Territory size decreases as the number of competitors increases in areas of abundant food (Davies and Houston 1984). At Nanshih Stream where fish farms provided a abundant food resource for owls, territories were smaller than at Sakatang Stream where there were no fish farms. In general, larger birds usually maintain larger territories (Schoener 1968). In Asian fish-owls, there is a positive correlation between body size and territory size. The large Blakiston Fish-Owl (*K. blakistoni*) which is 20% larger than the Tawny Fish-Owl (Voous 1988), occupied stretches of river 10–19 km in length in Russia (Pukinskiy 1973), whereas the smallest Malay Fish-Owl (*K. ketupa*) which is about 20% smaller than the Tawny Fish-Owl have territories measuring only 1–2 km in length along rivers in Borneo (Fogden 1973). We found that Tawny Fish-Owls favored riparian old-growth forests for roosting which may partially account for the distribution of the species in old-growth forest areas on Taiwan Island (Sun 1996). Old-growth forests, with their tall canopy (20–30 m), may provide greater safety from ground predators and their open nature may allow these large owls more maneuverably.

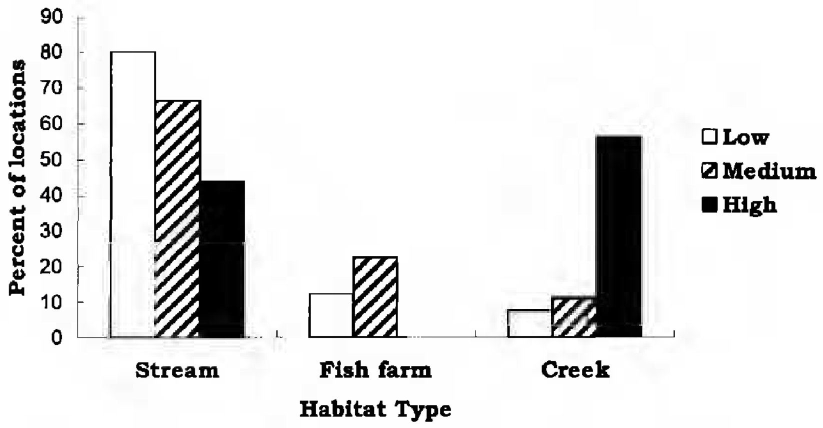

Figure 3. Proportions of nightly radio locations of four radio-tagged Tawny Fish-Owls at three different habitats during periods of low, medium and high water levels at Nanshih stream, Taiwan, September 1993–August 1996.

Hayward et al. (1987) found that Boreal Owls (*Aegolius funereus*) roosted near their last foraging site before dawn. This may explain why Tawny Fish-Owls roosted more frequently near fish farms. They also roosted at higher elevations during the hot summer and early fall seasons, probably in response to heat stress. Barrows (1981) also reported that summer roosts of Spotted Owls (*Strix occidentalis*) tended to be in cooler habitats, such as northern slopes and under dense canopy. A male observed nest guarding showed signs of heat stress when air temperatures were between 30–33°C in early May (Sun 1996). This might explain why two of the owls we studied moved uphill and downhill within their territories and why one owl temporarily left its territory moving upstream in summer.

Tawny Fish-Owls rely heavily on aquatic habitats because they eat mostly fish, amphibians and crustaceans (Sun 1996). Fogden (1973) noted that its uniquely-scaled feet make it well-suited to take such prey. We found that Tawny Fish-Owls preferred to use streams over creeks during low water levels. Most creeks in our study area were <5 m in width and some were even narrower, with dense overhanging vegetation blocking some channels along the creeks. This may have discouraged Tawny Fish-Owls, with a 1.5-m wingspan, from foraging in these areas despite their abundant food.

Tawny Fish-Owls increased their use of creek habitat when streams were flooded. This may have been due to the fact that creeks were much cleaner than streams and prey species like fish and crabs were much less difficult to find. This may explain why Tawny Fish-Owls also turned to fish farms as stream conditions deteriorated. Like Ospreys (*Pandion haliaetus*), fish-eating species like the Tawny Fish-Owl would be expected to leave turbid estuaries and fly to inland pools with clear water (Poole 1989).

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